

Particle Engulfment and Pushing at Solidifying Interfaces

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Obtaining uniform distribution of particles in the solid matrix during fabrication is an important issue in the manufacture of metal matrix composite materials. The main interactions in the introduction and incorporation of particles into the solid matrix especially when prepared by in-situ solidification are influenced by gravitational acceleration. The achievement of uniform distribution of particles in the matrix of these materials can only be achieved by understanding and controlling the particle interface interaction that determine when a particle is pushed or engulfed by the solidifying interface.

The Solidification Laboratory at The University of Alabama (Dr. Doru Stefanescu, principal investigator) in collaboration with co-investigators at MSFC's Space Sciences Laboratory are performing both experimental and theoretical work determining the critical velocity of engulfment of particles at a solidifying interface.

The objectives of the particle engulfment and pushing at solidifying interfaces, PEP, project are to gain a fundamental understanding of the physics of solidifying metal-ceramic particle systems, and to investigate the melt processing of metal matrix composites in the microgravity environment to obtain vital data for the processing of these important materials for terrestrial industry.

The experimental approach involves ground, aircraft low-gravity and orbital microgravity experiments that will compare data to comprehensive analytical and numerical models. Both metal and transparent matrices are to be used for the experi-

ments. Although the metallic systems currently have the most important applications, transparent systems allow the detailed study of the solidifying interface/particle interactions which are important for a comprehensive understanding of the process.

The x-ray transmission microscope (XTM) developed for solidification studies—under a NASA advanced technology development program—has been utilized at the MSFC's Space Sciences Laboratory. The instrument allows the imaging in real-time of particle pushing and engulfing during solidification. Solid-liquid interfacial interaction with particles and voids were studied. Spherical zirconia spheres 30 to 60 μm are clearly resolved in aluminum samples 5 mm in diameter. The technique allows the monitoring of critical velocities for pushing and engulfment while monitoring the interfacial morphologies in-situ to test theory. Recent theory predicts the interfacial curvature response to approaching particles or voids can be significant for metallic systems. The XTM was also utilized to help select from candidate samples the metal/ceramic particle samples for flight experiments.

Transparent matrix samples of biphenyl matrix containing glass particles, and succinonitrile matrix containing spherical polystyrene particles are being studied to quantify how liquid convection ahead of the solidifying interface alters the particle

behavior in the vicinity of the interface. Initial experiments were done on the NASA DC-9 parabolic aircraft. These experiments found that convection level and/or particle buoyancy significantly influences to critical velocity for particle engulfment. The critical velocity was found to increase, at the higher levels of natural convection, up to 40 percent. At the highest convection levels the particles failed to interact with the solidifying interface. A systematic study of current models showed that none could effectively quantify the observed convection effects on the critical velocity. These studies will be extended to near-convectionless conditions utilizing the middeck glovebox during the fourth United States Microgravity Laboratory Mission scheduled for launch in October 1997. The microgravity environment on orbit will allow the observation of particle pushing in steady-state conditions.

The initial Shuttle flight experiments for PEP metal matrix samples were done during the Life and Microgravity Sciences Spacelab mission in July 1996, utilizing the European advanced gradient heating furnace. The PEP, flight complement contained three samples. The first two with pure aluminum matrix and 500 μm ZrO_2 spherical particles. The third had Al-Ni eutectic alloy matrix and 500 μm ZrO_2 spherical particles. The thermal objectives of the experiment were successfully satisfied. The samples are to be delivered to the investigator team for analysis in fall 1996.

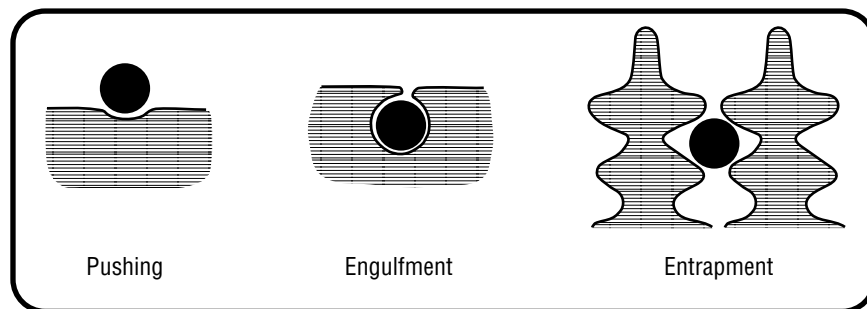


FIGURE 128.—Dynamics of particle-interface interaction.

Sen, S., Dhindaw, B.K.; Stefanescu, D.M.; and Curreri, P.A.: "Melt Convection Effects on the Critical Velocity of Particle Engulfment." Accepted for publication in *Journal of Crystal Growth*, Aug. 1996.

Sen, S., Dhindaw, B.K.; Stefanescu, D.M.; and Curreri, P.A.: "Melt Convection Effects on the Critical Velocity of Engulfment in the Biphenyl/Glass Particles System." Presented at the Eighth International Symposium on Experimental Methods for Microgravity Materials Science, Feb. 4-8, 1996, Anaheim, CA, 125 TMS Annual Meeting, to be published in proceedings.

Sen, S., Kaukler, W.; Curreri, P.; and Stefanescu, D. M.: "Dynamics of Solid/Liquid Interface Shape Evolution Near an Insoluble Particle." Submitted to *Metallurgical Transactions*, October 1996.

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University Involvement: University of Alabama in Tuscaloosa

Biographical Sketch: Dr. Peter Curreri is a materials scientist in the Microgravity Science and Applications Division at MSFC's Space Sciences Laboratory. He serves as the United States Microgravity Payload mission scientist. His research focuses on solidification processes for metals, alloys and composite materials utilizing the unique properties of low and microgravity. Curreri earned his Ph.D. degree in materials and metallurgical engineering at the University of Florida. He has worked for NASA for 15 years. 